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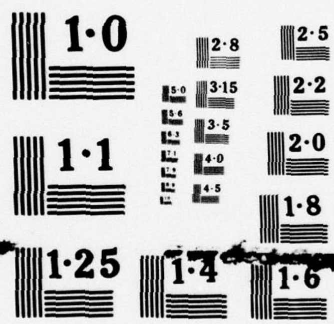

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Provides a method of assessing weapon jump that occurs during firing. Describes test setup, instrumentation, sighting and firing procedures, measurements, and computations. Applicable to artillery and tank weapons.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-102
*Test Operations Procedure 3-2-817 9 May 1978
AD No.

JUMP FIRING

1. SCOPE. This TOP describes procedures for determining the jump of artillery and vehicle mounted weapons that occurs during firing. Jump is the angular difference between a reference line established through a weapon tube before firing and the effective line of departure of the projectile as it leaves the weapon upon firing. The various types of jump are described in appendix B.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

ITEM	REQUIREMENTS
Test site	A firing range that is reasonably level for a distance of 185 meters forward of the weapon muzzle.
Jump targets	Panels made of expendable material (e.g., chipboard, plywood, etc.) that are large enough to provide five different aiming points and impact areas (fig. 1, para 5.1).

*This TOP supersedes MTP 3-2-817, 18 May 1966. 717 378

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2.2 Instrumentation.

ITEM	MAXIMUM ERROR OF MEASUREMENT*
Projectile velocity measuring equipment (TOP 4-2-805)	Velocity to 3,000 m/s ±0.1%
Weapon pressure measuring equipment (TOP 3-2-810)	Chamber pressure to 689,480 kPa (100,000 psi) ±2% of reading
Muzzle sight or bore reference telescope	Sighting reference only
Mount reference telescope	Sighting reference only
Gunner's quadrant	±0.2 mil
Meteorological equipment:	
Temperature	±0.2° C
Relative humidity	±1%
Barometric pressure	±0.01 in. Hg
Windspeed	±1 m/s

*Values may be assumed to represent ±2 standard deviations; thus the stated tolerances should not be exceeded in more than 1 measurement out of 20.

3. PREPARATION FOR TEST.

3.1 Planning.

a. Prepare a test operations checklist using appendix A as a guide and adding specifics for the test item and situation.

b. Design a data collection sheet(s) for round-by-round performance covering entries such as those in paragraph 5.2.

3.2 Weapon and Target.

a. Select a new weapon tube or one with at least 75 percent wear life remaining. Check stargage and borescope records to be sure that tube wear is within test requirements.

b. Emplace the weapon on a firing range with the gun forward at center traverse and near zero quadrant elevation.

c. Fire at least two rounds to seat the weapon firing base.

d. Check that trunnion cant does not exceed 1° in either direction and vehicle or carriage pitch does not exceed 2° in either direction. A

gunner's quadrant located across the weapon breech and on a normally level surface of the carriage or turret may be used for this check.

e. Where practicable, shade the tube from direct sunlight to eliminate temperature differentials that can cause tube bending.

f. Set up the jump target 150 to 185 meters from the weapon muzzle. Place the target level with the gun trunnions to within 1° and perpendicular to the line of fire to within 2°.

g. Measure and record the distance from weapon muzzle to target.

3.3 Instrumentation.

a. Install instrumentation to measure the following in accordance with the listed reference:

(1) Projectile velocity as described in TOP 4-2-805.

(2) Weapon chamber pressure as described in TOP 3-2-810.

b. Install the appropriate sighting instrumentation for the type of jump being investigated (app. B) and boresight the weapon as described in appendix C.

3.4 Projectiles. Weigh each projectile and determine the average weight for each type of projectile.

3.5 Data Required.

a. Model, type, and serial numbers of weapon and components (e.g., tube, mount, carriage).

b. Number of rounds and equivalent full charge (EFC) rounds fired from the tube and amount of wear on the tube.

c. Cant and pitch of emplaced weapon.

d. Distance from weapon muzzle to target.

e. Average weight for each type projectile.

4. TEST CONTROLS.

a. To control backlash effects lay the weapon on target from the same direction in azimuth and elevation for each round fired. When a gun or turret out-of-balance condition exists, establish the direction of lay to oppose the out-of-balance condition.

b. Restrict firings to times when, in the opinion of the test director, winds will not significantly influence firing accuracy. An estimate of crosswind effects on target impacts can be calculated as shown in appendix D.

c. Observe all range and facility safety SOP's throughout the test.

5. PERFORMANCE TEST.

5.1 Method.

a. Load and lay the weapon on the jump target using the telescopic sight attached to the gun mount (app. C).

b. Fire five rounds, re-laying the weapon on a different target aiming point (fig. 1) for each round.

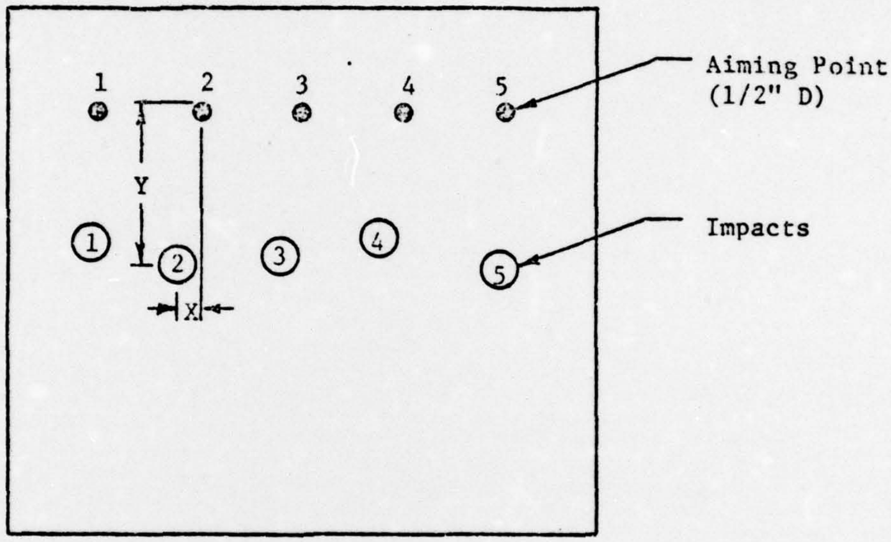

Figure 1. Jump Target.

c. Measure and record the horizontal (x) and vertical (y) impact distances from the target aiming point to the center of the impact hole for each round. Make measurements to the nearest 1.0 cm. Indicate the horizontal and vertical directions from the aiming point by plus (+) and minus (-) signs in accordance with normal rectangular coordinate notation; i.e., horizontal (x) values to the right of the vertical (y) axis are plus (+) while those to the left are minus (-), and similarly vertical (y) values above the horizontal (x) axis are plus (+) while those below are minus (-).

d. Repeat steps a through c for each ammunition type to be used with the weapon.

e. After firing each jump group (5 rounds) recheck the direct telescope or optical sight against the gun tube reference to make certain that changes in optical alignment did not occur. Refire the test phase (or include as corrections to the basic data) when optical alignment errors exceeding 0.1 mil are detected.

f. Repeat the entire test on three separate occasions.

5.2 Data Required. Collect and record the following data as applicable:

a. Date and time of firing.

b. Type of projectile and charge fired.

c. Tube round number.

d. Weapon firing elevation.

e. Horizontal and vertical impact distance from aiming point for each round.

f. Projectile velocities.

g. Weapon chamber pressures.

h. Projectile seating distance.

6. DATA REDUCTION AND PRESENTATION.

a. Determine the horizontal and vertical centers of impact from the point of aim of the group by algebraically averaging the individual coordinates. Because of small errors caused by drift, cant, wind, and such, jump data accuracy will not exceed 0.10 mil.

b. The horizontal center of impact expressed in mils is the horizontal jump. The vertical center of impact must be corrected for gravitational effect on the projectile during the time of flight from weapon to target.

$$\text{drop} = 1/2\ gt^2$$
$$\text{where } t = \text{time of flight}$$
$$g = 9.81\ \text{m/s}^2$$

For the above calculation, time of flight can be obtained by dividing the range from weapon to target (meters) by the muzzle velocity (meters per second).

c. Calculate the dispersion of the jump group, expressed as mils standard deviation. The dispersion of the jump group should not significantly differ from that expected from target firings for the ammunition being used. If it does, recheck the jump setup and conduct additional firings.

APPENDIX A
CHECKLIST GUIDE FOR JUMP FIRING

ITEM	YES	NO	NA
1. All operating personnel briefed on test requirements, special procedures, hazards, and any unusual aspects of test.			
2. Gun tube wear within test requirements.			
3. Weapon properly emplaced.			
4. Distance from muzzle to target measured and recorded.			
5. All required instrumentation calibrated, properly installed, and operational.			
6. Ammunition inspected, available, and identified.			
7. Wind conditions suitable for test firing.			
8. Weapon boresighted on target.			
9. Weapon lay established.			
10. Safety requirements accomplished (SOP checklist completed and SOP posted*).			
11. Required data recorded.			

*SOP 385-67 at APG.

APPENDIX B
TYPES OF JUMP

While jump is recognized, and to some extent its total effects measurable, the causes of jump have not been fully determined. For this reason, the techniques and methods of jump determination may change as the causes of jump are better understood. Among the possible causes are tube vibration and angular rotation during projectile travel, projectile dynamic and aerodynamic unbalance, and tube curvature from thermal or gravitational causes.

Jump is known to vary from weapon to weapon of the same caliber and type, with different ammunition types for the same weapon, and from occasion to occasion. It may occur in any direction but, for convenience, is normally reported by the use of horizontal and vertical coordinates.

a. The horizontal component of jump (x) is the difference between the horizontal angle of departure and angle of horizontal reference established through the weapon tube. It is designated as a plus quantity when the line of departure is right of the line of bore reference and as a minus quantity when the line of departure is left of the line of bore reference. For the purpose of calculating from impact coordinates, angular jump is assumed to originate at the weapon muzzle.

b. The vertical component of jump (y) is the difference between the vertical angle of departure and the angle of vertical reference as established by boresighting through the weapon tube. It is indicated as a plus quantity when the angle of departure is greater than the angle of fire and as a minus quantity when the angle of departure is less than the angle of fire.

Three types of jump are recognized, depending on which tube reference is selected: ballistic jump, effective jump, and apparent jump.

a. Ballistic Jump. Ballistic jump (fig. 2) is the angular difference between a reference line established through the bore over the last few inches of the muzzle before firing and the effective line of departure. The vertical component of ballistic jump is determined from a comparison of ranges and muzzle clinometer elevations observed in range firing (TOP/MTP 3-1-004) and is given in firing tables for field artillery weapons. Ballistic jump would be expected to exclude most of the tube droop and bend effects.

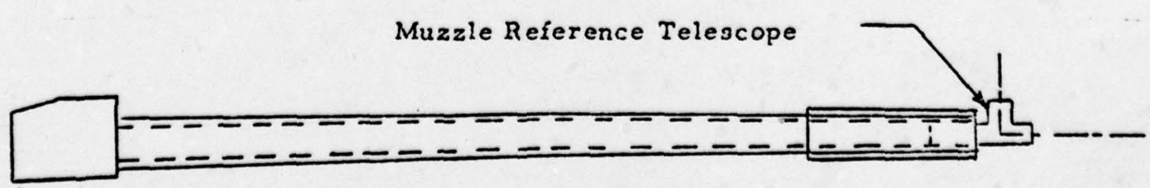

Figure 2. Ballistic Jump.

b. Effective Jump. Effective jump (fig. 3) is the angular difference between the line of departure and an extension of the breech bore centerline in the prefired state. In practice, this is related to convenient external reference points. Effective jump includes all of the effect of tube curvature on the line of departure.

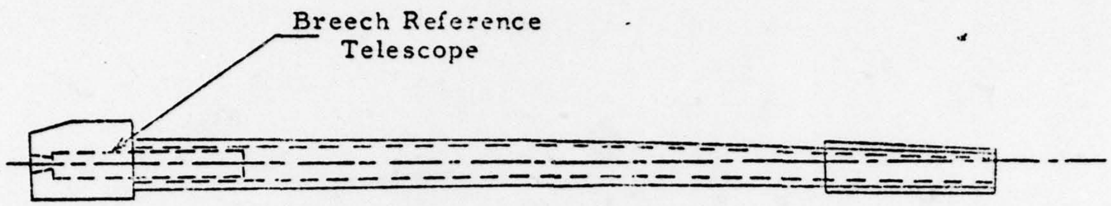

Figure 3. Effective Jump.

c. Apparent Jump. Apparent jump (fig. 4) is the angular difference between a line passing through the center of the muzzle and the center of the breech and the effective line of departure. This includes part, but not all, of the effect of tube curvature on the line of departure.

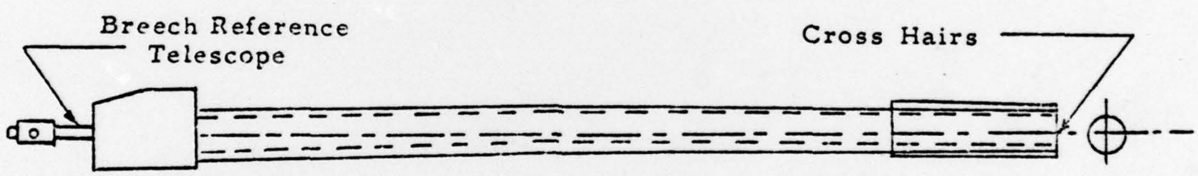

Figure 4. Apparent Jump.

APPENDIX C
BORESIGHTING

The accuracy of jump data depends largely upon the precision and repeatability of bore alignment on the target. Since loading of a weapon nearly always disturbs tube alignment, an external sighting system rigidly attached to the weapon mount but capable of adjustment must be used to realign the weapon on target after loading. On tank guns the coaxially mounted direct telescope is suitable; on artillery a telescope having a magnification from six to eight is adapted. This instrument must be rigidly mounted and not subject to misalignment as a result of firing shock. Boresighting shall be accomplished as follows:

a. Carefully align the tube on target (fig. 5), using either a muzzle boresight (ballistic jump), a chamber boresight (effective jump), or a breech-muzzle combination (apparent jump). Boresight devices for experimental purposes should magnify 10 to 20 diameters for best results.

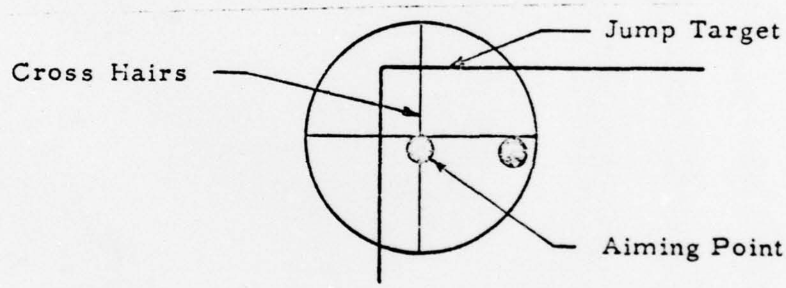

Figure 5. Alignment of Weapon Tube.

b. When using the reference telescope or boresight device, exercise care to avoid optical parallax (an error introduced into the line of sight by randomly positioning the observer's eye at the eye lens assembly). A pinhole aperture located at the eye lens is an effective means of minimizing parallax error.

c. Use an offset telescope at the weapon chamber to overcome interference or clearance problems when automatic loading mechanisms preclude direct lines of sight through the weapon to which they are attached.

d. Adjust the direct telescope to coincide with the same selected target point and secure boresight adjustments (fig. 6).

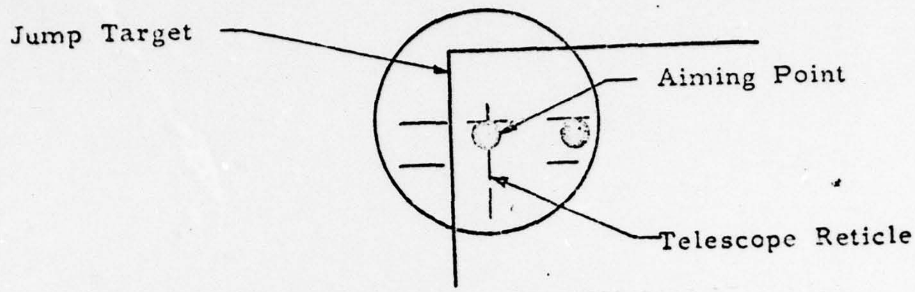

Figure 6. Alignment of Telescope.

APPENDIX D
CROSSWIND EFFECT ON TARGET IMPACTS

The effect of crosswind may be estimated for short ranges from the following:

$$W = 7.34 \frac{K\ V_W\ R}{1000\ C}$$

where: W = Crosswind effect at the target in mils.
K = Unit crosswind effect for a given resistance function and muzzle velocity (fig. 7).
V_W = Crosswind velocity in meters per second.
R = Range (meters).
C = Ballistic coefficient of projectile.

The ballistic coefficient and resistance function may be furnished by velocity measurements personnel if they are given information regarding the projectile type, weight, and velocity. The resistance function supplied will correspond to one of the six curves (G_1, G_2, G_5, G_6, G_7, or G_8) in figure 7.

Sample Computation

Given:

Crosswind (V_W): 4.5 m/s.
Range (R): 183 meters.
Gun: 90-mm, T139.
Projectile: APC M82 at 850 m/s; 24.11 lb.

From the velocity measurements personnel:

Ballistic coefficient (C): 2.163.
Resistance function: G_6.

Referring to figure 7:

K = 0.015 on curve G_6 for a muzzle velocity of 850 m/s.

Substituting:

$$W = (7.34)\frac{(0.015)(4.5)(183)}{(1000)(2.163)} = 0.042 \text{ mil}$$

For conditions of $\frac{R}{C}$ of 900 or less, these effects will normally be well within 10 percent except for muzzle velocities just above the velocity of sound.

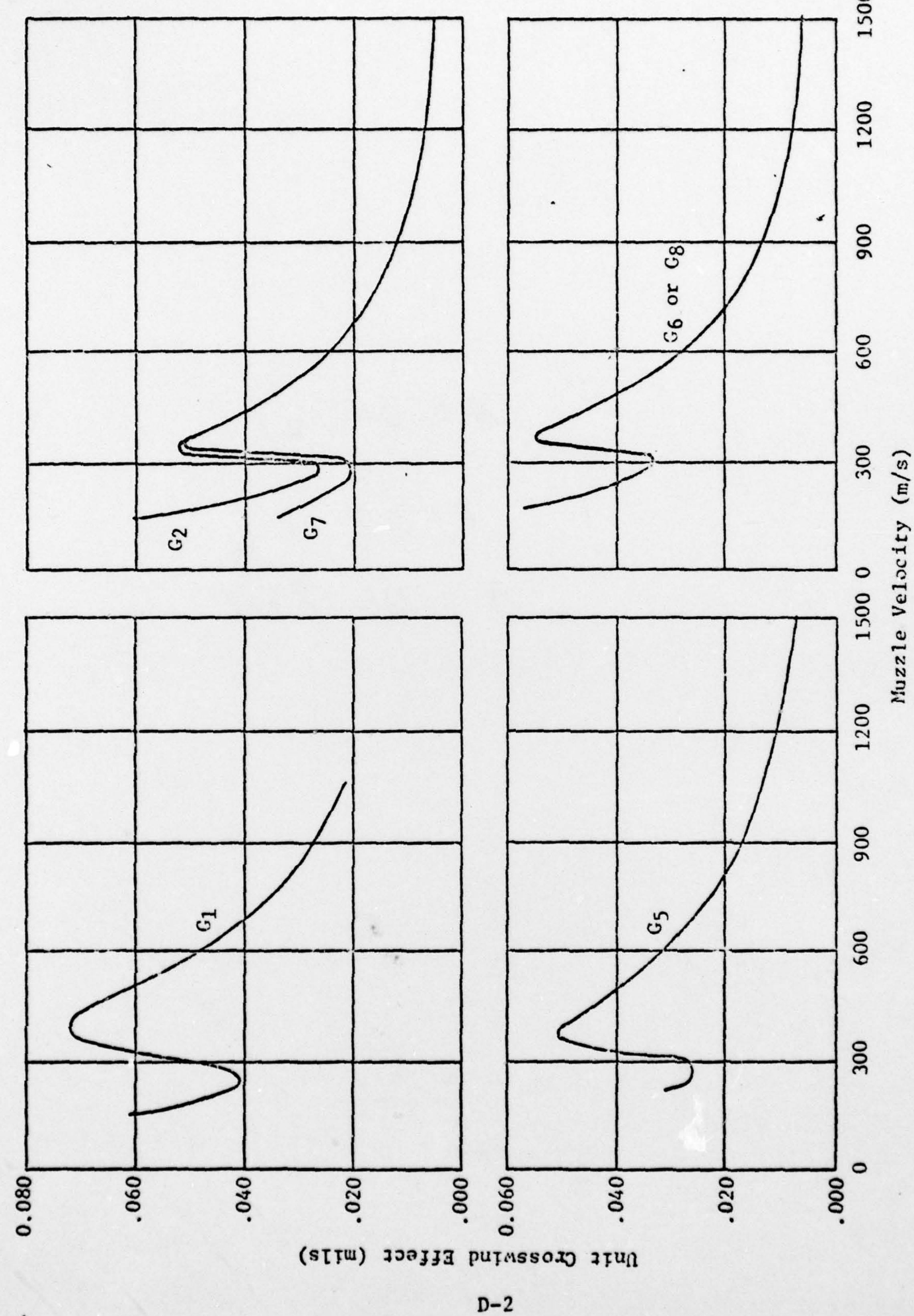

Figure 7. Approximate Crosswind Effects for Short Ranges.